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GLOBAL CLIMATIC CHANGES : PHOTOSYNTHESIS & PLANT PRODUCTIVITY

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ABSTRACTS OF PAPERS

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THE RESPONSE OF NATURAL ECOSYSTEMS TO THE RISING GLOBAL CO_2 LEVELS

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General patterns of response of plants, especially at the physiological level, to the rising CO_2 and the associated climate change are beginning to emerge. Enhanced photosynthesis and growth, particularly in C_3 plants, change in C/N ratio in plant tissues, increased allocation to underground parts, and particularly water use efficiency have been strongly documented.

The acclimatory potential of photosynthesis and growth to prolonged exposure to high CO_2 remains unknown.

Work at the community and ecosystem level has clearly shown that, in most situations, the response at the individual level may become highly modified and may not predict the response of communities. It is quite likely that the impact on productivity of ecosystems may result mainly from changes in species composition brought about by differential species response to elevated CO_2. The number and the identity of neighboring plants, the levels of environmental resources, the activities of herbivores, pathogens and symbionts are crucial to the way plants respond to elevated CO_2. Because of the complexity of these interactions, and our limited knowledge of them, our predictions about the future impact of the rising CO_2 and associated climate changes are tenuous. In fact for some ecosystems we cannot presently even predict the direction of the change that would result from increasing CO_2. Nevertheless, current work is giving us insights into the mechanisms of the response to CO_2 at the community level. Scenarios for response of arctic, temperate, and tropical ecosystems will be discussed.

SESSION I

UV-B RADIATION EFFECTS

Chairperson(s) : A. H. TERAMURA

E. WELLMAN

SOLAR UVB RADIATION MEASUREMENTS AT THE EARTH'S SURFACE : TECHNIQUES AND TRENDS

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Ultraviolet-B radiation (UVB) is the waveband (280-320 nm) containing the most energetic photons to reach the earth's surface from the sun. These photons initiate many biological reactions, often detrimental to life. Plants and other organisms have evolved to tolerate the UVB of their present climate, but changes in atmospheric ozone may alter this short wavelength radiation load producing stress. To assess the potential effect of this stress on agriculture and ecosystems requires a comprehensive knowledge of current levels of UVB. The majority of UVB measurements made to date have used broadband instruments, often with a biologically weighted output, but these do not provide sufficient data to fully study the mechanisms of plant responses. The rapidly changing shape of both biological action spectra and the solar spectrum across the UVB waveband necessitates spectral measurements of UVB to understand plant responses to changes in this waveband. Spectral UVB measurements are being made at Reading, providing data on which to base realistic research of UVB effects, and to monitor future changes in UVB that may result from stratospheric ozone depletion and tropospheric pollution. Requests, and sources, for this type of data are becoming more widespread and the techniques and types of measurement available will be discussed.

Physiological and Morphological Responses of Snapbean Plants to Ozone Fumigation as Influenced by Pretreatment with UV-B Radiation.

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Snapbean (Phaseolus vulgaris L. cv. 'Bush Blue Lake 290') plants were grown under enhanced UV-B radiation for 21 days in a growth chamber at 11.7 kJ m^{-2} d^{-1} of biologically effective ultraviolet radiation ($UV\text{-}B_{BE}$) prior to ozone fumigation (3 hr at 0.25 μmol mol^{-1}) to determine the influence of UV-B preconditioning on ozone sensitivity. This level of $UV\text{-}B_{BE}$ represents approximately a 20% decrease in stratospheric ozone for clear sky conditions at Beltsville, MD (39°N) on June 21. Biomass was measured at 8, 15, and 22 days. Plants grown from seed under enhanced UV-B radiation showed marginal cupping of the primary and trifoliate leaves, marginal chlorosis, and reductions in stem elongation and leaf enlargement compared to those grown in the absence of UV-B radiation. UV-B irradiated plants showed nearly a two-fold reduction in photosynthetic rate and a corresponding decrease in stomatal conductance and instanteous transpiration rate of the first trifoliate leaf. Chlorophyll concentration was also decreased in UV-B irradiated plants as determined by SPAD meter readings and measurements of leaf discs extracted in 80% acetone. UV-B treated plants subjected to ozone treatment showed greater leaf injury at 48 hr after fumigation than those pre-treated with only UV-A radiation. UV-B irradiation reduced PS II activity in the first trifoliate leaf as determined by chlorophyll fluorescence measurements. The inhibitory effects of UV-B irradiation and O_3 on PS II activity were additive. These findings demonstrate the need to conduct studies on interactions of UV-B radiation and other environmental stress factors in order to develop realistic assessments and valid models of projected changes in global climate.

FIELD STUDIES OF UV-B RADIATION EFFECTS ON PLANTS: CASE HISTORIES OF SOYBEAN AND LOBLOLLY PINE

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By far, the bulk of our understanding of the impacts of UV-B radiation comes from studies conducted in artificially controlled environments. Because environmental conditions within growth chambers of green houses are ubnlike those found in nature, plant responses under such conditions may neither quantitatively nor qualitatively resemble field responses. For instance, it is now widely known that plants grown in growth chambers appear to be more sensitive to a given UV dose than field grown plants. The basis for this difference in sensitivity comes from the fact that in artificial environments (growth chambers and green houses) a single factor is generally manipulated, while all other factors are either kept constant or are optimized for growth. Such single factor stresses are rarely experienced by plants outdoors. Instead, under actual conditions, plants would commonly experience simultaneous multiple stresses. For example, plants receive their maximum daily UV-B irradiatiance during the period of maximum air temperatures, visible irradiance, and evaporative demand for water. Unlike plants in growth chambers where nutrient solutions may be applied daily, most native plants and many agricultural crops grow in soils that are low or deficient in nutrients. In addition to these differences in physical factors, artificial environments almost always exclude biotic factors, such as the interactions between other plants, insects, diseases, etc. Finally, inherent limitations on size of controlled-environment condition make it impractical to conduct studies on crop yields, which must ideally be conducted in carefully designed field studies. Weighed against these shortcomings of controlled-environment studies are the enormous complexities associated with field studies. Here, daily fluctuations in environmental factors are superimposed upon longer-scale seasonal and annual fluctuations making interpretation extremely difficult and necessitating multiyear experimental designs. Both temporal and spatial variability often result in inconsistencies in plant responses between one year and the next. Experimental field plot studies will be described for a crop planbt, soybean (var. Essex) and a forest tree species, loblolly pine. In these field studies ambient levels of solar UV-B radiation have been supplemented by artificial UV-B radiation provided from fluorescent sunlamps. The effectiveness of UV-B radiation on physiological processes, growth and yield will be described for these plants grown under a full solar UV spectrum and in combination with drought.

Effects of UV-B and visible light on the reaction mechanism of photosynthetic water cleavage.

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Deleterious effects of UV and visible light on photosynthetic water cleavage in PS II membrane fragments from spinach were analyzed. Comparative measurements of a) 830 nm absorption changes reflecting the turnover of P680, b) oxygen evolution, c) activity of DCIP-reduction in the absence and presence of exogenuous electron donors, d) herbizide binding and e) fluorescence emission led to the conclusion that different target sites exist in PS II that are susceptible to UV and visible light stress. The detailed mechanism of destruction was found to depend on the functional integrity of the PS II complex and the light quality. Visible light predominantly effects the stabilization of the primary charge separation in PS II membrane fragments with intact catalytic site of water oxidation whereas in systems deprived of their oxygen evolution capacity the functional connection between P680 and Y_Z (Tyr-161 of polypeptide D1) is primarily interrupted with a rather high quantum yield. On the other hand, the catalytic site of water oxidation was inferred to be the most sensitive target to UV-B in PS II membrane fragments. Furthermore, nonphotochemical quenchers of excitation energy are generated by UV-B. It is emphasized that the deleterious effects of light stress cannot be ascribed to a single target site and a unique photochemical destruction mechanism.

INTERACTION OF HERBICIDE (DCMU) WITH UV-B RADIATION ON GROWTH AND PHYSIOLOGICAL ACTIVITIES OF WHEAT SEEDLINGS.

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Wheat seedlings, initially treated with 50 uM DCMU, showed marginal decrease in growth and pigment composition. However, the overall and PSII electron transport reactions decreased to approximately 50 % of initial level. UV-B irradiation of chloroplasts isolated from control and 50 uM DCMU treated seedlings caused differential inhibition of overall and PSII activity. The extent of UV-B inhibition was lower in DCMU grown seedlings. Analysis of thylakoids proteins indicates an increase in the level of Q_B protein in DCMU grown seedlings. These observations suggest that DCMU treatment causes structural modification of 32 kDa protein and this decreases the chloroplast sensitivity to UV-B radiation. This is supported by the observation that UV-B treated chloroplasts are inhibited to a lower degree by DCMU than the untreated samples.

RESPONSE OF PLANTS TO ULTRAVIOLET-B RADIATION AND METAL STRESS

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The assessment of multiple effects is very important in obtaining a more meaningful and realistic view of the current changes in the environment. *Picea abies* was grown from seed and exposed to UV-B radiation simulating a 20% decrease in the ozone layer near Lund, Sweden (54 °N, 13.4 °E). Analyses were carried out after 10 weeks of treatment. The combination of UV-B radiation and Cd^{2+} resulted in a reduction of needle dry weight and plant height. CO_2 assimilation and dark respiration rates also declined. In contrast to the treatments with UV or Cd^{2+} alone, the combination treatment also altered the kinetics of the variable fluorescence, namely in the F_{max} region.

U..V. INHIBITION OF THE DISSOLVED INORGANIC CARBON CONCENTRATING MECHANISM(S) AND ALTERNATIVE RESPIRATION IN UNICELLULAR GREEN ALGAE

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Because of low levels of CO_2 in air, plants and algae have processes for concentrating CO_2 internally to increase not photosynthesis and decrease photorespiration. Unicellular green algae and cyanobacteria develop dissolved inorganic carbon concentrating mechanism (often referred to as "DIC-pumps") when grown or adapted to air levels of CO_2 for 6-24 hours in the light. These DIC-pumps are suppressed when elevated levels of CO_2 (1-5%) are provided during growth. The induction or development of the pump is inhibited by the low levels of UV-B (280-320 nm, 0.2uW.cm^{2} to 2u.cm^{2}) but not by UV-A. A preliminary action spectra indicated maximum inhibition around 290 nm. These low UV treatments do not inhibit photosynthetic CO_2 fixation, but prevent an adaptive change in $K_{0.5}$ (DIC). Dissolved inorganic carbon concentrating mechanism and alternative, cyanide-resistant respiration, are both inhibited by SHAM, an inhibitor of the alternative respiration. Thus these two processes may be related. UV-A but not UV-B inhibited the capacity of alternative respiration in leaves and algae. A working model is UV-B inhibition of the formation of DIC-pump enzymes and UV-A inhibition of the alternative respiration.

SESSION II

CARBON DIOXIDE ENRICHMENT/BALANCE

Chairperson(s) : N. E. TOLBERT

V. S. RAMA DAS

ROLE OF PHOTOSYNTHESIS AND PHOTORESPIRATION IN REGULATING ATMOSPHERIC CO_2 AND O_2 CONCENTRATION

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Rubisco activity determines the amount of CO_2 fixation by the C_3 reductive photosynthetic carbon cycle and the amount of CO_2 release during photorespiration by the C_2 oxidative photosynthetic carbon cycle. Photorespiration also takes up O_2, which lowers net O_2 evolution during photosynthesis. Thus, photosynthetic carbon metabolism regulates CO_2 and O_2 compensation points, that are involved in establishing the atmospheric CO_2 and O_2 equilibrium levels. Excess photosynthetic energy is wasted by the C_2 cycle. For C_3 plants CO_2 equilibria can fluctuate between the CO_2 compensation point (60 ppm CO_2) and 1000 ppm CO_2 with photosynthetic assimilatory energy from full sun light. CO_2 concentrating mechanisms utilize part of the excess energy wasted by photorespiration to concentrate CO_2 in the chloroplasts by the C_4 cycle or by algal mechanisms for concentrating dissolved inorganic carbon (DIC pumps). Algal DIC pump activity is accompanied by accumulation of hydroxide ions in the medium which in turn can be used for lowering atmospheric CO_2 and forming carbonate deposits. More C_4 plants is not an apparent solution to lower the atmospheric CO_2. More research is needed on photosynthesis by algae which form long-life deposits of reduced carbon and carbonates.

A PHYCOLOGICAL APPROACH TO ALLEVIATING THE GREENHOUSE PROBLEM

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The greenhouse effect is currently one of the foremost environmental problems worldwide. It arises from a steady, gradual increase in the atmospheric CO_2 concentration largely as a result of man-made causes. Green plants fix CO_2 photosynthetically, thereby acting as sinks for the atmospheric CO_2. However, most crop plants are rather inefficient consumers of CO_2. Microscopic algae and cyanobacteria are much better fixers of CO_2 than are higher plants. Various microalgae act as strong traps or sinks of atmospheric CO_2 and hold great promise for countering the greenhouse effect. My research group in Banaras Hindu University has been engaged in exploiting *Spirulina major*, a protein-rich cyanobacterium, and a few nitrogen-fixing cyanobacteria, for reclamation of saline and alkaline wastelands, especially during the monsoons (June to August). These organisms grow luxuriantly in isolated, shallow ponds (fields) whose pH value ranges from about 8 to 9.5. These alkaline ponds effectively such in CO_2 from the air-water interface, and the CO_2 so absorbed is utilized by the procaryotic algae in photosynthesis. The single-cell-oil alga *Botryococcus braunii* has also been tested. It is a slow-grower but produces over 60% hydrocarbons and can be used as fuel. The larger surface-volume ratio of microalgae enables them to consume at least 15 times more of CO_2 per unit of land area than do crop plants. This makes a phycological approach to tackling the global greenhouse problem feasible and worth further enquiry.

Response of crops to increased carbon dioxide in the changing climate

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Extrapolations of the effect of carbon dioxide on photosynthesis have encouraged statements suggesting beneficial effects of increased CO_2 on crop productivity, particularly on C_3 plants, in the changed climate. These conclusions are based on the assumption that increase in photosynthesis rate is directly correlated with crop yield. Furthermore, almost all data obtained in controlled environment pertains to 600 ppmv of CO_2 or more concentration, mostly at temperatures which were optimal for growth and development. This extrapolation to field conditions is questionable on several grounds. Amongst these, the most important is the response of plant phenology which is not influenced by CO_2 concentration, but is strongly influenced by temperature. A higher temperature and reduced moisture have profound effect on crop productivity. Thus, the effects of CO_2 concentrations must be analysed in the context of the physiology of crop yield. In crops where no major genetic improvement occurred, the productivity has not changed in India though the CO_2 concentration has increased by 25% in the atmosphere in last 100 years. In addition, the regional predictions of GCMs are at present inadequate to draw any meaningful conclusion on the impact of CO_2 on agriculture. Therefore, it is important that we recognise limitations of the existing literature and identify research priorities for future.

ONTOGENY AND ECOPHYSIOLOGY OF PSEUDOTSUGA, ALNUS AND ACER SPECIES IN AN ENRICHED CARBON DIOXIDE ENVIRONMENT

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Controlled environment studies were initiated to evaluate the effects of CO_2 enrichment on the ontogeny and ecophysiology of three temperate tree species. The seedling response to two carbon dioxide concentrations were evaluated: ambient and 700 ppmv. The ontogeny of seedling root and shoot development from germination to dormancy was monitored. Seed germination, root and shoot elongation and leaf expansion were significantly influenced by CO_2 enrichment. Ambient carbon dioxide enrichment also indirectly delayed seedling bud-set and reduced tissue dormancy and cold-hardiness. Changes in seedling ontogeny in an enriched carbon dioxide environment apparently influences leaf gas exchange and mineral nutrition including tissue C/N ratios.

ABSTRACT

Assesment of limitations for photosynthetic rate under ambient and elevated CO_2

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Identification of photosynthetic traits limiting assimilation rate (A) is the primery requisite for genetic manupulation and improving crop growth rates.

At the existing CO_2 levels apart from CO_2 diffusive processes which is the major constriant it is necessary to quantify and charecterise the extent of limitations imposed by inorganic phosphate, photochemical and RuBISCO charecteristics.

The relative responses of the plant species to the predicted increase in CO_2 and temperature predominantly depends on maintanance of the expected increase in `A'. At high $CO_2$ levels other limitations may decrease `A' in some plant species. To minimise the constriants for the higher `A' changes in the end product synthesis and utilisation and adaptive changes in the extent of protein allocated to RuBISCO and changes in its charecteristics are important.

THE RESPONSE OF LEAF PHOTOSYNTHESIS TO ELEVATED CO_2

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Plant responses to increasing CO_2 levels may be classified as short-term and long-term. Long-term responses are more complex as they include ecosystem and organism level responses also, while short-term responses may be understood considering leaf-level processes only. The active CO_2 concentration for photosynthesis is that at the active sites of the carboxylation enzyme. It is lower than ambient due to the concentration drop on the leaf diffusion resistances. Under atmospheric conditions RuBP carboxylase in C_3 plants operates at CO_2 concentrations below the $K_m(CO_2)$. Under saturating CO_2 the rate is limited by the supply of the CO_2 acceptor ribulosebisphosphate (RuBP). The latter is resynthesized in the Carbon Reduction Cycle (CRC). The rate of RuBP resynthesis is determined 1) by concentrations of CRC intermediates, 2) CRC enzyme activities and 3) levels of energy cofactors NADPH and ATP. Maximum concentration of CRC intermediates is determined by the inorganic phosphate (P_i) pool in chloroplasts which is maintained constant. An increase in intermediate organic phosphates causes a decrease in free P. CRC enzymes are activated by the ferredoxin (Fd) thioredoxin system which needs higher levels of reduced Fd for more enzyme activation. NADPH level is efficiently stabilized by the allosteric inhibition of the Fd-NADP reductase by NADPH. ATP/ADP ratio is determined by the proton gradient and free P_i. Photosystem II efficiency is controlled by the intrathylakoid pH. The maximum possible rate of leaf photosynthesis at saturating CO_2 and light levels is achieved as a compromise between the controversial conditions. High ATP levels are necessary to support high CO_2 assimilation rates. At high assimilation rates the concentrations of CRC intermediates increase and that of free phosphate decreases. Accumulation of organic phosphates is emphasized when sucrose synthesis is restricted. In order to maintain high ATP with decreasing P. transthylakoid pH difference increases, the intrathylakoid pH, consequently, decreases. Decreasing intrathylacoid pH causes down regulation of the photosystem II efficiency which decreases the electron transport rate. In a steady state, the rate of electron transport stoichiometrically corresponds to the rate of ATP synthesis at an ATP/ADP ratio which is sufficiently high to drive the carbon metabolism at a rate equal to the electron transport rate. Concurrently, the level of free phosphate is sufficiently low to activate sucrose synthesis to the level corresponding to the carbon assimilation and electron traansport rates. In spite of almost a complete rate control by PSII there is still enough reduced Fd to guarantee the necessary activation state of the CRC enzymes.

EFFECTS OF ELEVATED CO_2 CONCENTRATIONS ON CARBON METABOLISM IN LEAVES OF C_3 PLANTS

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At canopy level, elevated CO_2 increases photosynthetic rates, leaf area, biomass and yield. Elevated CO_2 also reduces transpiration rate per unit leaf area, but not in proportion to reduction of stomatal conductance. With increasing leaf area and foliage temperature, photosynthetic water-use efficiency is increased. At cellular level, RuBP pool decreases with increasing CO_2. Organic phosphates increase at the expense of Pi, with chloroplastic PGA showing a marked increase. Hexose phosphates show an initial fall, followed by a marked increase. Sucrose synthesis is extremely sensitive to changes in CO_2 concentration. The [ATP]/[ADP] and the light scattering signal decline with increasing CO_2 pressure. These changes are generally interpreted as showing that the limiting element within the capacity for RuBP regeneration at high CO_2 pressures lies in the series of reactions between triose phosphates and RuBP, mainly because of mass-action ratios of RuBP regenerating reactions tending towards infinity at high CO_2 pressures.

ANALYSIS OF CO_2 ENRICHMENT ON CROP PRODUCTIVITY

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Agriculture can be affected in two broad ways: by the direct effects of CO_2 on plants and by warming effects of CO_2 on the climate. The results of the controlled environment generally show that the higher CO_2 concentration increases canopy photosynthesis and productivity, but may lead to decrease or increase in evapotranspiration (ET) under field conditions. However, ET may increase noticeably at elevated CO_2 with the increased temperature mediated vapour pressure deficit and leaf area. The effects of elevated temperature may be beneficial or avoided by genetical and agronomical measures in winter season irrigated crops, but will be detrimental in rainfed crops, particularly in dry hot season. Thus, at present it is unclear wheather the net effects of CO_2 and climatic change on Indian agriculture will be detrimental or beneficial.

PHOTOSYNTHETIC PERFORMANCE UNDER ENRICHED LEVELS OF CARBON DIOXIDE: AN ASSESSMENT AND PREDICTIONS

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The influence of higher than ambient levels of atmospheric carbon dioxide, the principal greenhouse gas, on plant photosynthesis are examined. The parameters of stomatal conductance, transpirational characteristics and of water use efficiency are considered. Higher carbon dioxide concentrations in the atmosphere are likely to alter the patterns of the partitioning of photosynthetically fixed carbon into different plant organs, starch/sucrose ratio and even phloem transport. Carbon dioxide enrichment might also affect the carbon allocation to dark respiration and other cellular metabolic processes. While looking into the effects of elevated carbon dioxide concentration on photosynthetic performance the differential responses of C3, C4 and of naturally occuring C3/C4 intermediate type plants are assessed in predicting whether the climate change would lead to modification of the evolutionarily stabilized pathways or to altered vegetational distribution.

CO_2 ENRICHMENT RESPONSES OF CHRYSANTHEMUM, CUCUMBER AND TOMATO: PHOTOSYNTHESIS, GROWTH AND YIELD

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Yield increases from CO_2 enrichment varied from 54% in cucumber fruit weight, to 37% in chrysanthemum dry weight and 20% in tomato fruit weight. To determine the basis for response differences, photosynthesis was modeled in chrysanthemum and growth, carbohydrates and photosynthesis were measured in 8 tomato cultivars. In chrysanthemum models CO_2-enriched leaves were more efficient at irradiances below 400 µMol $m^{-2}s^{-1}$,. At higher irradiances, ambient CO_2-grown leaves were more efficient because of greater CO_2 conductance. Measured at the same CO_2 concentration, ambient leaves had higher photosynthetic rates than enriched leavesbut *in situ* photosynthetic rates were still higher in enriched plants.In CO_2-enriched tomatoes, lower leaves were inrolled, chlorotic and purpled. We thought this was because of carbohydrate accumulation, possibly associated with feedback inhibition of photosynthesis. We found more starch in CO_2-enriched leaves, but the pattern of accumulation did not appear to account for changes in deformation through development and with source-sink treatments. Severity of leaf deformity was not correlated with low leaf photosynthetic rates, but was correlated with low root weights and low leaf potassium concentrations. The data suggest that some CO_2-enriched tomato cultivars partition carbohydrates to fruit at the expense of root biomass, leading to higher yields, but late-season nutrient stress.

PARTITIONING OF PHOTOSYNTHATES IN RESPONSE TO CO_2 ENRICHMENT

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The carbon exchange rate increases in plants grown under enriched CO_2 conditions. The growth of plants also tends to increase with an increase in atmospheric CO_2 concentration. This increase in growth has been shown to be due to increase in leaf area, dry weight of leaf and stem and number and size of the fruits. It is therefore assumed that these increases are due to change in photosynthate production and allocation of photosynthates to different organs. Plants grown under enriched CO_2 produce more soluble carbohydrates and starch. The soluble carbohydrates are distributed to various sinks according to sink demand. The partitioning of carbohydrates to either sugars or starch depends on growth stages and leaf position and age of the plant.

SESSION III

Photosynthesis and Environmental Stresses

Chairperson(s) : D. R. ORT

A. GNANAM

REGULATION BY LIGHT OF INACTIVE PHOTOSYSTEM II REACTION CENTERS IN LEAVES

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In higher plants approximately half the photochemical conversion of energy occurs through photosystem II (PS II). In view of this it is surprising that, at least in dark adapted leaves approximately one-third of the PS II complexes are inactive in that their turnover rate is 1000-times slower than active PS II complexes. Inactive centers are able to transfer an electron from P680 to Q_A, but the oxidation of Q_A^- is slow, exhibiting a half-time of 1.7 s at 23 °C (Plant Physiol. (1989) 90:765-772). We are investigating whether inactive PS II centers are altered in light adapted leaves. Measurements of the flash-induced electrochromic shift and the fluorescence induction in leaves following continuous illumination prompted us to develop the following working hypothesis: Inactive PS II complexes are converted in the light to an active form, PS II(Y), in which light drives an electron cycle within the complex. We propose that the PS II(Y) cycle quenches fluorescence, but does not transfer an electron across the membrane to Q_A. To account for the electron cycle we speculate that Q_A in PS II(Y) is reduced and may be protonated, and that the electron transfer pathway would include pheophytin and possibly low potential cytochrome b559, but not Q_A. The putative PS II cycle would serve to convert excitation energy to heat under conditions that electron transfer through active PS II complexes is light saturated, thereby protecting against photoinhibition. To be effective in dissipating excess excitation energy PS II(Y) would need to have a turnover rate of 500 e^-/s or faster.

FUNCTIONAL MODELS OF WATER OXIDATION COMPLEX IN PHOTOSYSTEM II

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Although many structural and spectral analogs of the water oxidation complex in Photosystem II have been reported in literature,in no case these model compounds have been able to evolve molecular oxygen from water. Present communication describes preparation and characterization of a tetrameric manganese cluster incorporating carboxylate and catechol ligand bridges which is capable of reconstituting manganese-depleted Pea subchloroplast particles and reactivating the photoinduced oxygen evolution and variable fluorescence.

ON THE MOLECULAR MECHANISM OF THE BICARBONATE EFFECT IN PHOTOSYSTEM II OF PLANTS AND CYANOBACTERIA: USE OF D1 AND D2 MUTANTS ALTERED IN SINGLE AMINO ACIDS.

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A working hypothesis for unique role(s)of HCO_3^-/CO_2 in photosystem II (PSII) of plants and cyanobacteria is now emerging. It appears that, at physiological pH, HCO_3^-/CO_2 may bind to certain amino acids on both D1 and D2, the reaction center proteins of PSII, and to iron between Q_A (bound to D2) and Q_B (bound to D1). HCO_3^-/CO_2 plays discrete and unique role(s) in PSII: its function may involve stabilization, by conformational means, of the reaction center protein that allows efficient electron flow in PSII, and efficient protonation of certain amino acids near Q_B^-. (See, e.g., Photosynthesis Research 19:85-128, 1988.) We shall review data on the differential sensitivity of mutants, altered in single amino acids, that support the involvement of both the D1 and the D2 proteins in the bicarbonate-reversible formate inhibition of PSII reactions. In D1 mutants of Synechocystis 6714, the resistance of cells to formate was in the following order (highest to lowest): A251V/F211S(AzV)>F211S (AzI) ≈ wild type> S264A (Govindjee et al., FEBS Lett 267:273-276,1990a); in D1 mutants of Chlamydomonas reinhardtii, the order of resistance was: L275F(Br202)>A251V(Mz2)>> wild type ≈ F255Y(Ar207)≈ V219I(Dr18)>>S264A(DCMU4) (Govindjee et al., Photosynth Res, submitted, 1990b). In site-directed mutants of Synechocystis 6803, the order of resistance was: wild type>>R233Q ≈ R251S suggesting that these arginine residues may stabilize HCO_3^-/CO_2 binding (Cao et al., Abstract, Midwest Photosynthesis Conference, 1990). In contrast to plants and cyanobacteria, purple (Shopes, et al., Biochim.Biophys. Acta 974:114-118, 1989) and green (Govindjee, Trost and Blankenship, unpublished, 1990) photosynthetic bacteria, that contain Q_A and Q_B on their M and L subunits, respectively, donot show any bicarbonate-reversible formate effects. Possible reasons for differences between the systems examined and a possible role of HCO_3^-/CO_2 in protecting against photoinhibition in PSII will also be discussed.

LIMITATIONS TO PHOTOSYNTHESIS INDUCED BY LEAF WATER DEFICIT IN FIELD-GROWN SUNFLOWER

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The diurnal cycling of leaf water potential (Ψ) in field-grown Helianthus annuus was used to investigate the cause of water deficit-induced limitation of net photosynthesis. Daily mid-afternoon decrease in Ψ of up to 1.5 MPa and in net photosynthesis of up to 50% were typical for irrigated sunflower. These mid-afternoon values were lowered further by prolonged drought treatment. There was a nearly linear relationship between the decline in net photosynthesis and reductions in leaf conductance over the course of the day yet the low, midafternoon rates of photosynthesis were associated with the highest intercellular CO_2 concentrations. These and other observations suggest that the daily decline in photosynthesis represents a "down regulation" of the biochemical demand for CO_2 that is coordinated with the diurnally developing need to conserve water, thus establishing a balanced limitation of photosynthesis involving both stomatal and non-stomatal factors. There were no indications that either short term or long term water deficits caused any malfunctioning of photosynthesis.

CROWN ETHER INHIBITION OF OXYGEN EVOLUTION IN BEET-SPINACH THYLAKOID MEMBRANES: POSSIBLE CHELATION OF CHLORIDE IONS.

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We have shown that K-Picrate-18-crown-6 (Crown) inhibits photo-electron transport activity of beet spinach thylakoid membranes. Micromolar concentrations of crown inhibits photosystem (PS) II electron transport without affecting PS I catalyzed electron transport. Analysis of oxygen evolution and chlorophyll a fluorescence indicates that the possible site(s) of inhibition is on the oxidizing side of PS II. The crown inhibition of PS II activity is largely reversible. We have investigated on the possible nature of crown inhibition of PS II activity particularly oxygen evolution. Our results indicate that one of the modes of action of crown ether is largely linked to removal of ions, mostly chloride ions. Besides chelation of ions, crown ether seems to induce changes affecting photochemical function. We suggest that crown compound may be useful in studies PS II functions in thylakoid membranes. (Supported by ICAR USDA Project FG-IN-679 grant No. IN ARS 402 to PM).

MOLECULAR BIOLOGY OF MEMBRANE PROTEIN COMPLEXES IN THYLAKOID MEMBRANES OF CYANOBACTERIA

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Photosynthetic electron transport is one of the principal bioenergetic processes in plants and cyanobacteria. The overall yield of major crop plants as well as agronomically important cyanobacteria is very much dependent on the efficiency of photosynthetic 'light' reactions. Various chemical and biotic stresses affect the rates of these reactions and lead to decreased plant productivity. In order to manipulate the overall efficiency of this process, detailed biochemical and genetic analyses of the protein complexes participating in light reactions in thylakoid membranes are warranted. Toward this goal, we are using model cyanobacterial systems to study two pigment-protein complexes photosystem I (PSI) and photosystem II (PSII). For our studies on the PSI complex, we have chosen Anabaena sp. ATCC 29413 as our experimental organism. This filamentous cyanobacterium has a PSI complex whose composition is remarkably similar to that from vascular plants. We have recently purified a highly active PSI preparation from this organism and have identified twelve different polypeptide subunits in it. The reaction center of PSI resides on two large proteins (A and B). In addition, two iron-sulfur acceptors are localized on a small protein (C). We have cloned the genes, psaA, psaB and psaC, encoding the A, B and C proteins, respectively from the genome of Anabaena 29410. Exogenous DNA may be introduced into these cyanobacterial cells via conjugal transfer from E.coli. We are currently attempting to create targeted mutations in these genes, using recombinant DNA techniques. Anabaena 29413 cells are capable of growth in complete darkness. Thus we expect that cells will remain viable when its PSI complex is inactivated. For our studies on the PSII complex, the experimental organism is Synechocystis sp. PCC 6803. This unicellular cyanobacterium can very easily be transformed by the simple addition of exogencus DNA. Moreover, Synechocystis 6803 cells can grow even in the absence of any PSII activity. Currently we are creating site-specific changes in the cytochrome b559 protein of PSII in Synechocystis 6803 to understand its functional role in photosynthesis.

LIGHT-RESPONSIVE REGULATION OF PHOTOSYSTEM II GENES IN THE CYANOBACTERIUM *SYNECHOCOCCUS* SP. PCC 7942

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The D1 and D2 proteins of the photosystem II reaction center are encoded by two small gene families in the cyanobacterium *Synechococcus* sp. strain PCC 7942. Each of these families contains members that are expressed at low levels under typical laboratory growth light intensities equal to or below 125 $\mu E \cdot m^{-2} \cdot s^{-1}$, but whose expression increases markedly upon transfer to higher light. The *psbAII*, *psbAIII*, and *psbDII* genes exhibit this mode of expression, which is regulated primarily at the transcriptional level. The *psbAI* and *psbDI* genes are expressed at higher constitutive levels than the other genes, and show little evidence of transcriptional regulation. However, the *psbAI* message appears to have a shorter half-life at high light than under low light conditions. Proteins from *Synechococcus* soluble extracts bind specifically to the upstream regions of members of both gene families, and may play a role in regulation of the genes. Current experiments are aimed at determining the primary sensor for light intensity, such as a photoreceptor or a change in redox state, and the signal transduction pathway that results in altered gene expression. A major goal is to understand whether altered gene expression is an adaptation to changing conditions to better utilize available light or to protect the photosynthetic apparatus from environmental stresses.

HEAT SHOCK AND OTHER ABIOTIC STRESS EFFECTS ON PHOTOSYNTHESIS AND GENE EXPRESSION IN CHLOROPLASTS.

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Very similar to factors like excess CO_2 or oxygen containing free radicals, low temperature, photo-inhibition, photo-bleeching, increasing leaf temperature, heat shock deminishes the photosynthetic activity of the chloroplasts.

Primary site of heat shock (hs) effects are on thylakoid membranes and the ordered reactions connected with the light induced water splitting site and photophosphorylation. The CO_2 fixing stromal enzymes are resistant to heat shock directly, eventhough they may get affected indirectly. Of the two photosystems, PSII is more sensitive to Heat shock and the protection and recovery are good if they are pre adopted to Heat shock.

The heat shock proteins (HSPs) in the range of 21-26 kDa, and the HSP family of 60 kDa are known to be organelle oriented, of which the smaller HSPs are coded in the nucleus and transported across and the HSP-60s are coded and made in the chloroplasts. The same HSPs are induced under certain chemical stresses such as Arsenite, Cadmium and physical wounds. The DNA damaging agents or the free radical forming compounded like methyl viologen and Juglone though cause considerable stress on plants are not countered with HSP induction. The salinity stress induces a different set of polypeptides. The possible role of HSPs in their providing tolerance to certain chemical stresses and the role of a more generic "Stress Proteins" will be discussed in detail.

PLANT RESPONSE TO ELEVATED CARBON DIOXIDE AND CLIMATE CHANGE: THE ROLE OF SINK DEMAND AS AFFECTED BY TEMPERATURE AND NUTRITION

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Doubling atmospheric CO_2 from the current concentration (340 cm^3 m^{-3}) increases dry matter production of C3 plants by some 30% as determined from experiments, largely on crop species under optimal nutrition and temperature. These conditions allow the growth of organs, including those for storage of assimilates, at the maximum rate which is determined genetically. Sub-optimal temperatures and nutrition decrease growth and the capacity for both assimilation and storage, thus limiting the response of dry matter accumulation to elevated atmospheric CO_2. Differences in the growth of organs resulting from the environment will affect both the total assimilate accumulation and the proportion of products. A 'source-sink' model of assimilate production and accumulation, based on plant responses to temperature and phosphorus and nitrogen nutrition will be given, to evaluate the information required to interpret and predict plant response to CO_2 and climate change.

The Use of Action Spectroscopy in Estimating the Effects on Living Systems Due to the Increased UV-B Penetrating a Depleted Ozone Layer.

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Action spectroscopy is most simply defined as the measurement of a biological effect as a function of wavelength. Crude action spectra (the term "action spectrum" was not coined until the nineteen forties), were first used in the Nineteenth Century to identify chlorophyll as the chromophore most responsible for the growth of plants. However, the most noted action spectrum (AS) was completed by Gates in 1930 and was the first clear evidence that nucleic acids were the genetic material. This spectrum showed that both the survival and mutation of E. Coli cells were most effected by wavelengths of ultraviolet radiation (UV) that closely paralleled the absorption spectrum of DNA. Although not readily accepted, this result, and the subsequent experiments that showed that UV could readily mutate DNA, which, in turn, could be repaired, led the way for many important contributions of UV photobiology to studies in cellular and molecular biology

AS in the range of substantial UV absorption by DNA (220 - 310 nm) were then completed with a variety of eukaryotic cells, including human cells in culture. No fundamental differences in response were obtained when roughly compared with those discovered in bacteria. It was thought that experiments at longer wavelengths (>310 nm) would yield results that could be estimated from the results already known at shorter wavelengths. When more powerful radiation sources became available in this longer wavelength region, the results obtained were not predictable nor easily interpreted. Cellular survival and mutation are effected by UV-A (320 - 380 nm) to a larger degree than can be explained by absorption in DNA alone. Some cells that were very sensitive to UV-C (190 → 290 nm), such as certain lines of XP cells, were no more sensitive to UV-A than normal cells. Other cellular molecules, including endogenous pigments specific to some cells, are apparently the significant chromophores in the UV-A, although for some biological end-points (eg. mutation) the final alteration is still believed to be DNA. The primary chromosomes for mutagenesis in this region could thus be non-DNA sensitizes that are chemically matched to the photon energy, and which, in turn, act as intermediaries in relaying the absorbed energy to DNA.

But just when you thought that you had completed your last AS, events have proved that more detailed AS are needed. The recent realization that stratospheric ozone (the ozone layer) is being depleted has resulted in a need for AS for a variety of organisms, For example, terrestrial plants and aquatic micro organisms may be the first living things to be effected by the increased UV-B (290-320 nm) that will penetrate a depleted ozone layer. Even modest decreases in crop yields could lead to human starvation. Disruptions or changes in organic ecosystems (perhaps caused by increased UV-B effects on plankton) may be among the first measurable bio-effects noted. However, predictions regarding these two systems are difficult because of the limited number of AS reported, especially under ambient conditions. Perhaps the inclusion of "polychromatic" AS will be central to the solution of this problem. Here the normal ambient background is supplemented or depleted with selected UV wavelengths.

So, as has often been the case in the past, new directions in photobiology first need accurate AS. Some of these studies have already been reported, or are currently underway. More will be needed. Both UV-A photobiology and ozone depletion have pointed us to what has to be cone - Action Spectra Again.

ABSCISIC ACID--AN INDICATOR OF GUARD-CELL WATER STRESS

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More than two decades after its discovery as a plant growth regulator, abscisic acid continues to mystify plant physiologists who seek to understand its role in conserving water. The difficulties primarily relate to two problems. First, most studies are pharmacological (i.e., the effects of exogenous ABA are determined). Second, there is usually ambiguity in the measurement of an "active" ABA pool. In our investigations, we hope to provide results that complement typical studies, as enumerated. Following perturbation of leaf-water status (e.g., excision and rapid leaf desiccation), *Vicia faba* L. leaflets are rapidly frozen and freeze-dried. Individual guard-cell pairs are dissected and assayed for an abscisic acid with an enzyme-amplified ELISA (*Proc. Natl. Acad. Sci.* USA 85:2584; *Physiol. Plant.* 78:495-500; *Plant Physiol. in press*). We have found that guard cells accumulate abscisic acid more rapidly than other cells do during stress imposition. In our present experiments, guard cells of leaves of different ages--which differ in ability to synthesize ABA--are being assayed for ABA during stress imposition. The results of these and ancillary experiments will be reported.

THE RELATIONSHIP BETWEEN PHOTOSYSTEM 2 ACTIVITY AND CARBON ASSIMILATION IN LEAVES

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The quantum efficiency of PS2 electron transport (ϕ_{PS2}) in a leaf in any given environment is determined by the product of the efficiency with which an absorbed photon can be trapped by a PS2 reaction centre and the number of 'open' reaction centres. These last two parameters are estimated by the product of variable to maximal fluorescence (Fv/Fm) and the coefficient for photochemical quenching of fluorescence (qP) respectively, consequently allowing a rapid estimation of ϕ_{PS2} to be made from fluorescence parameters. In leaves of C3 plants, in which photorespiration has been suppressed, and of C4 plants, which have negligible photorespiration, ϕ_{PS2} was found to be linearly related to the quantum efficiency of CO_2 assimilation (ϕ_{CO2}) over a wide range of environmental conditions. These data demonstrate that both the number of 'open' PS2 reaction centres and non-photochemical quenching of excitation energy by thermal dissipative processes associated with PS2 contribute directly to decreases in the quantum efficiency of non-cyclic electron transport and carbon assimilation in leaves.

SESSION IV

CROP MODELLING

Chairperson(s) : S. K. SINHA

J. D. EASTIN

Eastin,J.D., A.Dhopte, P.K. Verma, M. Livera-Munoz, T.Gerik, V.Gonzalez-Hernandez and F.Zavala-Gracia; Department of Agronomy, Institute of Agriculture & Natural Resources, University of Nebraska, Lincolin, NE 68583-0817, U.S.A.

Global warming predictions vary but may include a 1 to 5 C range depending on the area and the time span in the estimate. Reduced water supplies are usually associated with increasing temperatures. Developing new adapted cereals efficiently to fit the projected warmer and often drier climates requires temperature and water response consideration of essential physiological and developmental processes. Data primarily from wheat and sorghum experiences will be used to illustrate potential approaches to optimizing productivity in increasingly stressful environments. Photo -synthesis, being the plant energy capturing system, merits close evaluation. The influence of temperature, water and CO_2 level on photosynthesis is considered elsewhere primarily. However, data suggest that photosynthesis, though obviously essential, frequently is not the first in rank of essential grain yield-limiting processes. Data analyses from many sources suggest that the influence of temperature and water on crop developmental pace exerts an overriding influence on yield through control of the seed number and seed size components of yield. Therefore, greater understanding of control of growth and differentiation is of paramount concern. Effective stress screening programs are possible which serve to concentrate stress resistance mechanisms. Utilization of newer biotechnological methods to manipulate stress mechanisms will generally require more detailed understanding of the mechanisms.

MODELING PLANT RESPONSES TO CLIMATE CHANGE: AVOIDING NON-SENSE

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Plants differ in strategies for coping with abiotic or biotic stresses, based upon differences in physiology, morphology and phenology (PMP; Gutschick, 1987). Differential stress effects on photosynthetic and ontogenetic growth processes (C supply and demand) may frequently determine which is limiting primary productivity at the ecosystem level. Such differential responses are difficult to predict, using a materials balance approach, even for the most intensively modeled species. Spatial heterogeneity in stress strength further complicates the prediction. We will discuss various classification systems for plant PMP characteristics and stress strategies, in an effort to generalize sensible plant community responses to potential climate change. Emphasis will be on assessing available information about morphology.

MODELLING THE EFFECTS OF CO_2 INDUCED CLIMATIC CHANGE ON CEREAL CROPS

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Climatic change has implications for world agricultural production which are starting to be appreciated. Using a well-tested model of the growth and development of wheat the change in dry matter productivity for coincidental increases in CO_2 concentration and temperature are explored. The main prediction is for harvest indices to fall. The model also suggests that there will also be an increase in nitrate-loss from crops under warmer, wetter conditions. In attempting to develop strategies which will amollorate the combined effects of increased temperature and changes in water supply use is made of the model to define crop ideotypes that will be better adapted to altered conditions. The paper will conclude with discussion of the areas of investigation necessary for further progress to be made.

DYNAMIC VERSUS STEADY-STATE LIMITATIONS TO GAS EXCHANGE IN A SOYBEAN CANOPY

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Leaves within a soybean canopy may receive as much as 50 to 90% of the available PAR in the form of sunflecks with most lasting less than 5 seconds. Under these conditions, steady-state gas exchange measurements do not provide an adequate description of the limitations to photosynthesis of these leaves. In this study we have examined the dynamics of photosynthesis of soybean leaves with the objective of determining the role of transient photosynthetic responses in the carbon gain of canopies. For leaves in the shade that are suddenly exposed to a sunfleck, a photosynthetic induction requirement limits the maximum rate of CO_2 exchange that can immediately be achieved. This induction requirement results from 1.) a limitation in RuBP regeneration capacity in the first 1-2 minutes following a light increase, 2.) a requirement for light activation of Rubisco requiring about 5 minutes for completion and 3.) stomatal opening requiring up to 30 minutes for completion. When sunflecks are frequent but brief, postillumination CO_2 fixation resulting from the buildup and utilization of high-energy metabolite pools may contribute significantly to the utilization of sunflecks and at least partially offset the induction limitations. The role of these dynamic responses in determining the carbon gain of soybean leaves in canopies will be discussed.

SESSION V

AGRO - AND ECO - SYSTEM

Chairperson(s) : R. S. PARODA

C. J. NELSON

THE GLOBAL METHANE CYCLE

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The global cycle of methane is driven by emissions around 550 tg/yr from both natural and sources related to anthropogenic activities, particularly the production of food and energy. Major sources are rice agriculture, domestic ruminants, and wetlands. Methane is removed from the atmosphere mostly by reacting with OH radicals. Some methane is removed by the soils. Over the past decade methane concentrations have been increasing at about 1%/yr or 16 ppbv/yr. A record of atmospheric methane extending back 150,000 years has been constructed from the analysis of polar ice cores. It shows that, during this time, methane concentrations have never been more than half of present levels. The recent increase of methane is probably caused by increasing emissions. Some of the increase may also be attributed to decreasing levels of OH.

MEASUREMENT OF GREEN HOUSE GAS EMISSIONS IN INDIA

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Measurements of methane and other green house gases carried out in India to estimate Indian contribution to the global budget are reported. Methane emission from rice paddy fields grown under different geographical, environmental, soil, pH parameters and having different paddy varieties has been studied at New Delhi, Karnal, Dehradun, Hyderabad and West Bengal. Effect of different parameters on methane emission is discussed. A first order estimate indicates a contribution of 3 to 9 tg of methane from Indian rice paddy fields and is only 6% of the global methane budget due to rice cultivation. Methane emissions from sources other than paddy fields are also discussed. Results obtained on Nitrous Oxide emissions show significant efflux from grass land and waste land in India.

AGROECOCLIMATES OF INDIA

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Earlier workers used rainfall and soils alone for identification of agroecoclimates (Panabokke, 1979, Murty and Pandey, 1978, etc.). However these approaches have not very clearly brought out the ecoclimatic features as mere rainfall alone is taken along with soils. Hence in this paper a index of moisture adequacy which combines both rainfall and temperature and is a ratio of actual water need to potential water need is utilised. The use of this index in combination with the soils of a given area reveals the agroecoclimates on the lines done by Panabokke for FAO using rainfall alone and soils. The agroecoclimates so obtained also provide useful information of the potential crops and vegetation supported in the area. Such a delineation of agroclimates for the whole of Indian subcontinent and also for Andhra Pradesh and Maharashtra states is presented. The crop potential in different agroecoclimates are given for optimising the cropping pattern.

GLOBAL CLIMATIC CHANGE : REGIONAL SCENARIO OVER INDIA

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An overview of the global climatic change is presented in relation to contemporary changes over India. Documented evidences and observations on climatic change scenario over India are presented using proxy data, historical accounts, dendroclimatic data and available instrumental records. The major global warm and cold periods/epochs are examined in relation to the performance of the monsoon rainfall over India. The possible contemporary changes in the climate of the earth influenced by the activities of man particularly by the release of CO_2 into the atmosphere are examined. The results of GFDL, GISS and NCAR Atmospheric General Circulation Model simulation for the doubling CO_2 scenario are examined. The outputs of these models reported in the literature in respect of precipitation, temperature and soil moisture distribution are examined and the doubling CO_2 scenario presented by the models over the monsoon region is interpreted in terms of the climatic change and consequent agricultural production over India.

CAN MAJOR DEFORESTATION EFFECT CLIMATIC CHANGE?

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In the forest-hydrology link, distinction has to be maintained between rainfall and monsoon as rains could also be of cyclonic, orographic or convectional origin. In contrast to a deforested barren zone, a dense extensive forest-cover may influence convectional rainfall because of its lower albedo, aerodynamic surface roughness of its canopy, absence of dust particles and presence of organic debris in the atmosphere serving as effective condensation nuclei. Case studies on forest-rainfall/number of rainy days relationship have been reviewed. As vegetation types and plant productivity depend on rainfall and length of dry season, major deforestation could shift the vegetation pattern towards drier spectrum and reduce productivity.

CLIMATIC CHANGE AND PLANT GROWTH

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ABSTRACT

The contribution of green house effect on agriculture directly as well as thru hydrological responses has been discussed. Role of satellites in describing large spatial scale agricultural vegetation activity and its relationship with air temperatures based parameters, description of satellite based sensing capabilities to monitor atmospheric ozone, temperature and humidity profile, Earth Radiation Budget and the year 1998 onwards opportunities in agricultural remote sensing have been discussed.

PRIMARY PRODUCTIVITY OF INDIAN WETLANDS AND THEIR FUTURE SCENARIO

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Wet lands are wide ranging natural and man-made permanent, temporary or seasonal water bodies or water saturated lands, lentic or lotic, fresh, brakish or saline such as lakes, ponds, many paddy fields, rivers and flood plains, impoundments, streams, peats, bogs, marshes swamps, marine tidal belts and mangroves, deltas, estuaries and brackish back waters. They have profound ecological and economic importance. Mostly they are highly productive but ecologically fragile liable to degradation and degeneration under the prevailing anthropogenic pressures and climatic changes due to dumping of solid and liquid wastes, toxic material, run-off inputs of pesticides and fertilizers, silt from degrading watersheds, dam constructions and over exploitation. Standing crop biomass and net production rates in Indian wet lands have been measured by a number of University botanists. The studied wet lands range from cold to very cold Himalayan lakes like Dal, Anchar, Mansbal, Surinsar, Nilnag in Kashmir and Nainital lakes in UP to strongly seasonal cold winter and hot summer North Indian plains around Varanasi (ponds and river corridors), Jaunpur (Gujar lake), Ballia (Surha lake), Gorakhpur (Ramgarh and other lakes), Bhagalpur (Ganga river), Udaipur, to warm belts of Madhya Pradesh (Doodhdhari lake) and Andhra (Kolleru lake). Maximum standing crop dry biomass and annual net production is in emergent and marsh zone vegetation of *Eleocharis*, *Cyperus*, wild rice and cultivated floating rice (upto 10-40 t ha^{-1} yr^{-1}) followed by prolific growth of ubiquitous *Eichornia crassipes*. Unless the water shed vegetation is protected, application and runoff of pesticides and fertilizers in catchment are regulated, effluents are adequately pretreated and judicious management steps are taken, the future scenario of Indian wet lands are too bleak.

WHAT DRIVES GLOBAL CLIMATE AND ECOSYSTEMS? : AN OVERVIEW

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The earth climate responds to astronomical events, solar variation, internal atmospheric processes, southern oscillation and Cenozoic uplift of mountain range. Vesuvius/Avellino may be one source of seventeenth century BC climate disturbances. Production of green-house gases from human activities has begun to warm the globe, particularly at high latitude, cause less precipitation and less moisture in the soil at lower latitude. A minority contradicted the global warming. But an International Panel assessing green-house warming denied the validity of objection raised by them. Analysis indicates that the ozone layer depletion due to CFCs reduces stratospheric heating rate and delays the break down of southern polar vortex. Increase in the flux of uv-B radiation at the earth surface alters its energy balance. Main culprits are the glass-house gases and ozone layer depletion, also driving the global ecosystems. Global warming may migrate prairie forest border to north, decrease crop yield by 3-17% and shift in geographical locations of potential crop regions by several hundred kilometers. Ozone hole could reduce the rate of production of phytoplankton harming the entire southern ocean ecosystems.

IMPACT OF RISE IN TEMPERATURE ON THE PRODUCTIVITY OF WHEAT IN INDIA

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Wheat is a major cereal grown during winter in the cooler parts of India. It already faces temperatures which are unfavourable for full expression of its yield potential. Yields are usually better in the north Indian wheat belt because of cooler conditions as compared to wheat grown in central and western parts of India. Productivity is reduced in all areas during the warmer years. It is expected that even moderate rise in global temperatures *i.e.* 0.3 - 0.5°C per decade, due to greenhouse effect, will, influence productivity. The major setback to the productivity of wheat under higher temperature conditions is caused by reduction in the size of the wheat plant due to shortening of crop duration which in turn is associated with hastening of various developmental stages. Reduction in grain number, leaf area, biomass and 1000 grain weight are other adverse effects of high temperature. In the event of severe global warming, other crops may replace wheat in India. With moderate rise in global temperature, however, wheat cultivation may be sustained in its present areas provided heat tolerant types are produced and made available for commercial cultivation.

THERMAL RELATION OF LIGHT UTILIZATION AND BIOMASS PRODUCTION IN UPLAND COTTON (*Gossypium hirsutum* L.)

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The excessive use of fossil fuel resources is likely to enhance global temperature owing to green house effect. Thus an understanding of the possible impact of rising temperature on crop photosynthesis and productivity would help in mitigating the above adverse effects.

Cotton in India is grown as a rainy season crop. However, planting and harvest time depends on temperature regime prevailing from region to region. Mean temperatures between 25° to 35°C have been found conducive for flower formation and boll development and any departure from the above range lead to perceptible decrease in crop yield. Since biomass and fruiting coefficient (harvest index) are the prime components of crop yield, it is intended to evaluate the impact of rising temperatures on solar radiation utilization and biomass production under tropical environment. The present study indicates that increase in temperature within the prevailing range under Delhi conditions affected adversely the quantum of solar radiation absorption vis-a-vis biomass production. Analysis of growth components reveals that rising temperature exerted negative influence on crop growth rate, mean leaf area index and specific leaf area whereas its impact on relative growth rate, net assimilation rate and leaf weight ratio was of positive nature. Leaf conductance was correlated negatively with temperature.

It appears that cotton crop followed a definite strategy in combating the adverse influence of increasing temperatures experienced during the cropping season. To begin with increase in leaf area ceases and the crop growth rate reaches the compensation point (i.e. zero CGR). As the temperatures increase further, interception and absorption of photosynthetically active radiation becomes almost negligible. Dark and photorespiration overtakes photosynthesis and results in loss of biomass. Select genotypes were tested for their performance under tropical summer (March-June) and promising genotypes were identified.

POSSIBLE IMPACT ASSESSMENT OF FUTURE GLOBAL CLIMATIC CHANGE BASED ON PHYSIOLOGY AND PHENOLOGY OF PLANTS ALONG ALTITUDINAL GRADIENT

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Carbon dioxide, temperature and UV-B relation change with altitude. While CO_2 and temperature decrease with increasing altitude UV-B increases. Thus, high altitude climate represents the pre-industrial periods with respect to CO_2 and temperature and post-industrial period in relation to UV-B radiation. The comperative study of physiology and phenology of plants at different altitudes thus provides an opportunity to predict, although roughly, the future pattern of changes in ecosystem with respect to the global climatic changes. The present day CO_2 level at about 3000 m elevation in Indian Mountains is around 275ppm whereas in valleys at about 550 m elevation it is roughly 340 ppm, which shows the magnitude of CO_2 changes which has taken place during last 100 years in the atmosphere. The transplant studies of plants at various altitudes have been conducted for a long time. The results can be interpreted in terms of the global climatic changes. Many of the high altitude plants when grown at lower elevation show increase in photosynthetic rates indicating thereby positive effect of elevated CO_2 on photosynthesis in mountain plants. Such comparison gives an idea that the "greenhouse effect" will be favourable for mountain plants. If the temperature increases by 2 to $3^{o}C$, the growth period will be extended in cold climates leading to increase productivity. It is certain that the phytosociology will be effected to a considerable extent because CO_2 enrichment is reported to have an adverse effect on the reproductive cycle of short day plants and favourable effect on long day plants, indicating thereby the vegetational pattern will change considerably. However, roughly it can be predicted that with present pattern of global climatic changes the germplasm from higher mountains will be more productive and resistant than the germplasm from lower elevations.

HEAT FLUXES IN NATURAL AND MANAGED ECOSYSTEMS

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Global warming by 2000 A.D. is known to induce catastrophic ecological changes in the biosphere. More than one causal factor is attributed to the global warming. The deforestation coupled with the expansion of agricultural base has modified the surface albedo patterns. The comparative data on the heat fluxes from different terrestrial ecosystems and the identification of sources and sinks within a ecosystem are essential in not only developing more realistic models useful in predicting the 'greenhouse effect' but also in understanding its impact on the biological productivity of different communities. The differential heat fluxes creat different heat regimes which in their turn influence the gross primary productivity of ecosystems. The available data on the heat regimes is reviewed, keeping in view the anticipated enhancement in the atmospheric temperature of the biosphere.

IMPACT OF GLOBAL CLIMATIC CHANGES ON PHOTOSYNTHESIS AND PRODUCTIVITY OF TROPICAL RICE

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The effects of increase in temperature through green house effects of enhanced carbon dioxide and other atmospheric gases, UV-B radiation by destruction of ozone column, aberrant rains through deforestation, flooding and salinity resulting from sea rise on rice have been analysed. Adverse influence of high temperature on spikelet fertility, photosynthesis and sink potential on tropical rice was discussed. The need to tailor the rice varieties to high temperature, drought spells, water-logging and salinity has been emphasised so as to meet the impending challenges of global warming and associated problems during 21st century.

PERSPECTIVES OF GREEN-HOUSE GASES IN CLIMATIC CHANGE AND PLANT PRODUCTIVITY

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Increasing concentrations of green-house gases such as carbondioxide (CO_2), methane, nitrogen dioxide, ozone (O_3) and chloroflurocarbons in the atmosphere warrant global warming and their buildup is likely to lead to surface temperature rise of 1.5-5.5°C and changes in precipitation pattern over the next 50-75 years. Reductions in crop yield and increase in crop water demands are projected due to unfavourable climatic changes. Adverse effects of global warming due to increase in CO_2 concentration may be outweighed by increased photosynthesis as doubling of CO_2 can increase photosynthesis in soybean, wheat and maize by 35, 25 and 10 per cent, respectively. C_3 plants respond more favourably than C_4 plants. Higher levels of O_3, sulfurdioxide and oxides of nitrogen near the surface prove harmful to plant growth. Reduction of O_3 in the stratosphere lowers the protective effect in blocking incoming ultraviolet radiation which endangers plant and human life. The paper reviews the perspectives of green-house gases in relation to climatic change and crop productivity.

INTRASPECIFIC VARIATION IN SENSITIVITY TO UV-B RADIATION IN RICE (ORYZA SATIVA)

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Studies were conducted under glasshouse conditions to examine the relative sensitivity of 41 cultivars of rice to enhanced ultraviolet-B radiation (UV-B, 280-320 nm). Under conditions simulating 10% and 40% reductions in column ozone for the tropics, UV-B was found to alter root and shoot growth, shoot height, tiller production and leaf area in rice seedlings, but both the magnitude and direction of the response varied with cultivar and UV-B exposure. Preliminary results suggest that high-yielding varieties such as IR36 and IR74 which are widely planted in Asian lowlands, are more sensitive to UV-B than many other cultivars such as Fujisaka 5 or Star Bonnet. Identification of UV-B-tolerant cultivars might be an important means of mitigating against potential detrimental effects of UV-B under ozone depletion.

UV-B EFFECTS ON DEVELOPMENT OF PHOTOSYNTHETIC APPARATUS, GROWTH AND PRODUCTIVITY OF HIGHER PLANTS

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The influence of UV-B (middle ultraviolet radiation of the spectral region 280-320nm) on the photosynthetic apparatus, growth and productivity of plants has been studied using the erythemal lamps in laboratory and field conditions. It has been confirmed that the effectiveness of UV-B varies among the species of plants. The character of arabidopsis chloroplasts pigment system response on UV-B depended on leaves age: the young leaves had deep but reversible damages; the damages of old leaves were only quantitative and irreversible. The susceptibility of pigment system of photosynthetic apparatus and growth function of cotton seedlings decreased under higher level of visible light. It was demonstrated that growth and harvest yield reduction of cotton and soybean plants caused by UV-B intensity increase were approximately identical under the same field conditions.

EFFECT OF UV-B RADIATION ON <u>VIGNA SINENSIS</u> L. SEEDLINGS GROWN AT DIFFERENT TEMPERATURES.

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The interaction of growth temperature (10-40^{o}C) and UV-B radiation on photosynthetic apparatus of *Vigna sinensis* L. seedlings was studied. Seedlings grown at 40^{o}C had lesser UV-B impact than those grown at 20 and 30^{o}C as measured by changes in pigment levels and photosynthetic electron transport. Reducing the growth temperature to 10^{o}C resulted in poor chlorophyll biosynthesis, however under UV-B enhanced radiation 3-4 fold increase was noticed. Seedlings grown at 20 and 30^{o}C under UV-B enhanced radiation showed gradual loss of PS II activity 36 h after onset of treatment. No such inhibition was noticed in seedlings grown at 40^{o}C. This could be attributed to the reorganization of thylakoid membranes and changes in the accessibility of electron donors and acceptors.

EFFECT OF SOLAR UV-B EXCLUSION ON GROWTH OF MUNGBEAN

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The solar UV-B radiation was eleminated using filters and mungbean plants were allowed to grow from germination to maturity under normal field conditions. The exclusion of solar UV-B caused increased plants growth in terms of plant height. The increased shoot length was also accompanied by increased leaf area, leaf and shoot dry weight. The dry weight of pod and seed also increased in plants growth under UV-B eleminated conditions. This suggests that present level of solar UV-B is already high enough to cause decline in the growth of plants.

EFFECT OF ENHANCED ULTRAVIOLET-B (UV-B) RADIATION ON STOMATAL APERTURE AND LEAF SURFACE IN RICE

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Increased UV-B (280-320 nm) radiation as a result of stratospheric ozone depletion has influenced growth and development of various crops and alarmed environmentalists. Since UV-B radiation is directly incident on the leaf surface, structural alterations may occur on the rice leaf surface that can affect the sensitivity of the leaf to UV-B radiation.

Selected rice cultivars were subjected to enhanced UV-B radiation (based on 40% ozone depletion) for four weeks at seedling stage. Stomatal aperture and number, and silica content and wax distribution were assessed. Numbers of stomata on the adaxial and abaxial leaf surfaces were reduced by UV-B treatment. However, varietal differences were observed. IR74, the most sensitive cultivar to UV-B, had the greatest reduction while IR64 had the least. Per cent reduction in stomatal number was higher in the adaxial surface suggesting a direct effect of UV-B on stomatal development. The reduction appeared to be due to the collapse and degradation of stomates. Stomatal aperture was also affected by UV-B irradiation. Large reduction in stomatal opening was observed with 4 weeks UV-B treatment. Reopening of the stomates after UV-B treatment was much slower in sensitive cultivars compared to less sensitive ones. Amount of silica per unit dry weight and per leaf area increased in IR45 and IR74. Wax density also increased. The increase was accompanied by the reduction in leaf dimensions. The results revealed that enhanced UV-B radiation may later rice leaf surface structure and composition directly.

COOPERATIVE INTERACTION OF PHOTOTROPHIC AND HETEROTROPHIC TISSUES DURING CARBON DIOXIDE PHOTOASSIMILATION

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Photosynthetic carbon metabolism of plants containing a great number of heterotrophic cells in a photosynthetic organ is shown to be characterized by a high level of β-carboxylation reactions. The activity of enzymescarboxylating phosphoenol pyruvate is located not only in Phototrophic but also in heterotrophic tissues. The dynamics of cell sap pH changes and the content of products of carbon dioxide fixation indicate that the final products of photosynthesis may be a source for synthesis of phosphoenol pyruvic acid in heterotrophic cells.

THE ORIGIN AND EVOLUTION OF C_4 METABOLISM OF THE CHENOPODIACEAE AS A RESULT OF GLOBAL ARIDIZATION OF CLIMATE

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About 40 C_4 spesies from 5 tribes and 14 genus of the Chenopdiaceae in arid zone of Middle Asia were examined for their ecological distribution, anatomy and biochemical features (first products of photosynthesis and activity main enzymes of carbon metabolism). The survey shows that general way evolution of carbon metabolism was the same in both subfamily (Chenopodioideae and Salsoloideae): $C_3 \rightarrow$ NAD-ME $\rightarrow$ NADP-ME. Within the NAD-and NADP-ME subtypes was detected biochemical groups on the basis of relation between activity of aspartate-aminotransferase and NADP-malic enzyme, which changed from 3-5 to 200 times. This groups was distinguished not only biochemical features, but Kranz-anatomy types and life forms. We supposes, that deep biochemical specialization of C_4 pfotosynthesis of the Chenopodisceae reflects of the process of ecological differentiation of plants during aridization of climate in Afro-Asiatic region.

COORDINATION OF VEGETATIVE AND FLORAL DEVELOPMENT IN CEREALS. IMPLICATIONS OF CLIMATE CHANGE.

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Leaf emergence, number of leaves per shoot, tillering, floral development and stem elongation are coordinated processes. In each case temperature is a dominant factor affecting rate and final number of organs. In winter (vernalisation requiring) genotypes, the rate of emergence and number of leaves per shoot and timing and rate of floral development are affected by temperature, but in different senses. Shoot development interacts with growth via changes in canopy development and partition of dry matter between the ear and vegetative organs to determine yield components and harvest index and therefore final yield. The main effect of temperature and other environmental factors on these processes has been quantified, but there are complex interactions. A model based on the simulation of leaf emergence and number of leaves integrates the developmental processes and predicts the possible interactions consequent on temperature change.

INFLUENCE OF AN ELEVATED CO_2 LEVEL ON PARTITIONING OF C AND N IN PLANTS FROM NATURAL VEGETATIONS

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The influence of an increase in CO_2 level in the atmosphere from 350 to 700 ppm on growth and chemical composition was studied in *Plantago* species and in *Urtica dioica* during the period of exponential growth of the vegetative plants. In all cases considerable stimulation of relative growth rate by the enhanced CO_2 level was found, but the stimulation did not last. In ecotypes of *Plantago lanceolata* this was caused by changes in investment of carbon: relatively more C was invested in sugars and starch in the leaf. A detailed growth analysis with *Plantago major* and *Urtica dioica* showed that dry matter allocation in the leaf was changed: the specific leaf area was decreased by the high CO_2 treatment. The high CO_2 treatment caused a reduction in leaf N concentration of *Plantago major*, but not of *Urtica dioica*.

EFFECT OF PARENTAL GENOTYPES ON THE PHOTOSYNTHESIS AND DROUGHT RESISTANCE OF TRITICALES

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An attempt was made to understand the differential contribution of wheat and rye parents on the moisture stress susceptibility of octoploid and hexaploid triticales for their photosynthesis, productivity and water status. It was observed that(1) the hexaploid triticale generated from tetraploid durum(HD 4545) wheat, was relatively more susceptible to moisture stress compared to octoploid obtained from hexaploid aestivum(C 306) wheat for their photosynthesis, growth and productivity.(2) The stem reserves of hexaploid did not transfer much to ear development and retained the translocant in the stem due to moisture stress, whereas in octoploid the translocation of stem reserves to ear was relatively more.(3) The stomatal behaviour for controlling the transpirational flow and water use helped the octoploid triticale in maintaining the optimum water potential under stress condition.(4) Such a maintenance of water potential and transpirational flow was not observed in hexaploid triticale. Taken together these mechanisms confer higher degree of stress adaptability to octoploid compared to hexaploid triticale.

ASSOCIATIONS OF PHOTOSYNTHESIS AND WATER RELATIONS WITH RELATIVE HUMIDITY AND PHOTOSYNTHETICALLY ACTIVE RADIATION IN BLACK GRAM AND CLUSTER BEAN UNDER RAINFED CONDITIONS

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Quantification of influence of weather components on physiological processes will help understand and predict effects of changes in weather on crop productivity. Leaf water potential (LWP), and rates of stomatal conductance, photosynthesis (P) and transpiration (T) were correlated with changes in relative humidity (RH) and photosynthetically active radiation (PAR) during pod growth stages in rainfed black gram (*Vigna mungo* (L.) Hepper) and cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) for two seasons. RH and PAR were negatively associated. Correlation between LWP and RH was positive and that between LWP and PAR was negative. Stomatal conductance in black gram was more sensitive to changes in RH and PAR than in cluster bean. Influence of RH and PAR on P and T was positive or negative or non-significant depending on occurrence of drought in the season and on crop species.

PHYSICAL AND BIOCHEMICAL FACTORS LIMITING PHOTOSYNTHESIS UNDER OPTIMAL AND SUBOPTIMAL CONDITIONS IN SUNFLOWER

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Limitations exerted in the rate of photosynthesis by some physical factors like somatal conductance and electron transport via PSI and PSII under moisture stress condition and during stress alleviation, and the regulation by biochemical factors such as the assimilates of photosynthesis (sucrose and starch) and related enzymes (Rubisco and SPS) under optimal conditions were investigated in sunflower. Under mild to moderate levels of moisture stress both stomatal resistance as well as electron transport limited photosynthesis while under severe stress conditions non-stomatal limitations (light reactions) predominated. During the flowering stage, however, non-stomatal limitations dominated at all levels of moisture stress. On the other hand, under optimal conditions the level of assimilates (sucrose and starch) present in treated leaves of girdled, detopped, shaded and defoliated plants failed to influence photosynthesis. Moreover, sucrose accumulated in leaves did not cause any feedback inhibition of SPS, thereby ruling out the possibility of its involvement in the regulation of photosynthesis in sunflower.

RESPONSES OF *BRASSICA* SPECIES TO SOIL MOISTURE STRESS

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Brassica juncea outyielded *B.napus* and *B.campestris* (yellow sarson) under both adequate and inadequate soil moisture regimes by virtue of slow senescent, longer reproductive phase sustaining profuse branching and high pod number. The seed yield was similar in *B.napus* and *B. campestris* under irrigated conditions. Withholding irrigation reduced the seed yield in all the three species, the decline was less in *B.juncea* but drastically more in *B.campestris* than in *B.napus*. The strong vegetative build-up, high leaf area index and high photosynthetic efficiency supported the larger number of pods in *B.napus* under depleting soil moisture despite its short post-flowering phase exposed to high temperature. The leaf area development and the formation of reproductive structures were markedly sensitive to soil moisture stress in *B.campestris*. High RuBP case activity and CO_2 exchange rates in pod wall (comparable to that of leaves) in light and the reduction in seed yield under dark indicated that the current photosynthesis contributed about 50 per cent of seed yield. Substantial activity of PEP carboxylase in developing seeds demonstrated its involvement in non-photosynthetic fixation of CO_2. While the per cent oil contents in seeds decreased, the per cent seed protein and its major component glutamic acid increased under soil moisture stress. The migration of remobilized nitrogen from stem which accounted for at least 60 per cent of seed protein was not impaired by drought. The activity of glutamine synthetase was markedly reduced but glutamate dehydrogenase activity remained almost stable in stressed leaves suggesting its active involvement in ammonia metabolism in stressed environment. Synthesis of a plant type, early flowering with strong vegetative base is conceived for increasing productivity in Oleiferous *Brassica* species.

EFFECT OF IRRIGATION ON FLOWERING, YIELD AND ITS ATTRIBUTES OF CHICKPEA UNDER DIFFERENT DATES OF SOWING

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Two chickpea (*Cicer arietinum* L.) varieties C 235 and BG 268 were raised under restricted soil moisture and high soil moisture on four sowing dates during each of the two seasons 1987 and 1988. Both varieties had similar flowering duration, per cent fruit set and grain weight per pod. However, C 235 gave higher yield (40%) as it produced more pod number per unit area (40%) as a result of more flower number per plant. Grain weight per pod of crops raised under restricted soil moisture was higher by 35% which over compensated for its lower pod number. Linear regression co-efficient between yield contributing characters and sowing days of the year showed that for every one day delay in sowing a) grain yield/m^2 declined by 1 g; b) pod number of BG 268 and C 235 declined by 5 and 7-10 pods/m^2 respectively; c) flowering duration under restricted soil moisture was reduced twice as fast as under high soil moisture and fruit setting was improved by 1% by delayed sowing of 2-3 days in both cultivars.

SEASONAL INFLUENCE ON GROWTH AND DEVELOPMENT OF RICE VARIETIES (*Oryza sativa* L).

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Growth of four early elite rice cultivars were compared under kharif (rainy) and rabi (winter) seasons during 1986 with average temperature of 28.3°C and 25.0°C respectively during entire crop period. The difference between day and night temperature during reproductive and ripening period was higher in winter (12.2°C) than in rainy (7.3°C) season. Upto 50 days after transplanting net assimilation rate and canopy photosynthesis were more in winter season crop, while crop growth rate was greater in rainy season crop. However at subsequent stages, crop growth rate, relative growth rate and total dry matter were higher in winter season crop with high grain yield (4.6 t/ha in rainy and 4.9 t/ha in winter crop). Evidently the better productivity of the winter season crop could be attributed to high solar radiation combined with high day and low night temperatures during grain formation period which are conducive for potential grain filling and grain yield.

GROWTH, PHOTOSYNTHESIS AND PRODUCTION

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The work was aimed at elucidating the role of growth and photosynthesis, as basic components of productivity, in the accumulation of phytohormones, inhibitors and biomass. The following pea mutants were used: dwarfs (inhibited stem development), aphyllous forms (inhibited foliage development), albinos (chlorophyll deficiency). It was shown that the dwarfs contained a very low quantity of phytohormones and the increased amount of natural inhibitors (polyphenols, ABC). The albinos plants lost the ability of chlorophyll synthesis, had less carotenoids and a higher quantity of polyphenols on the background of low ABC. The photosynthesis in aphyllous forms occurred in tendrils, stipules, and stems. Their response to phytohormones and retardants was similar to the corresponding leafy forms. The role of the three forms in the production process is discussed.

THERMAL EFFECTS ON EARLY GROWTH AND SEED-COTTON YIELD IN UPLAND COTTON (Gossypium hirsutum, L.)

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In north-Indian agroclimatic region cotton is grown as rainy season crop. During the preflowering phase, ground temperatures often exceed 40°C resulting in poor growth. However, with the advent of rains growth picks up and flowering phase begins and continues till the night temperatures drop below 20°C. It is intended to understand the impact of temperature on preflowering growth and seed cotton yield. Seven sowings at two weeks interval beginning from April middle were made. Data were collected on plant growth during preflowering phase, position of the first fruiting node, number of bolls, boll weight and seed-cotton yield and compared with cumulative temperature and relative humidity. The results suggest that seed-cotton yield decreased progressively with delay in sowing and traced to decrease in number of bolls and higher position of the first fruiting node. Boll weight was also reduced, though to a lesser extent. During preflowering phase, plant growth registered as dry weight of stem and leaves respectively, increased with delay in sowing and is comparable with decreasing temperatures and relatively higher humidity during the corresponding periods. It is suggested that cotton sowing in the second week of May was the most beneficial for plant productivity.

HIGH TEMPERATURE INJURY: EFFECTS OF LATE-SOWING ON GRAIN GROWTH AND YIELD IN WHEAT

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High growth temperatures are important factors in wheat cultivation in Punjab, where during grain-filling, these often rise well above the moderate ones suitable for wheat growing. The problem is further accentuated in case of late-sown wheat. Studies conducted at PAU have shown that late-sown wheat encounters high temperature during reproductive stage which results in reduced grain filling duration and hence a decrease in yield. Mechanisms of high temperature injury during the reproductive phases include pollen development and germination; anther dehiscence; fertilization, spikelet number, their fertility and grain-filling. Reproductive growth comprises series of 'irreversible and noncompensatory processes' that appear to be differentially sensitive to high temperature. Period coincident with possible spike emergence and pollen development has high temperature environment leading to male sterility. Furthermore, photosynthetic responses to heat stress of the wheat ears and flag leaves will be separately involved. If greater temperature fluctuations occur, as predicted by the greenhouse model, periods of hightemperatures during the grain-filling period are likely to increase in both frequency and severity.

EFFECT OF FOREST CONVERSION ON VEGETATION AND SOIL CARBON AND FUNCTIONAL TRAIT OF RESULTING VEGETATION

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Major vegetation types and other landuses for an Indian dry tropical region were delineated using IRS 1A LISS I scene of 16 October 1988. This area has experienced rapid changes due to anthropogenic forcing. Carbon stored in vegetation and soil was estimated. Forest basal area was linearly related with C stored in vegetation, soil and total ecosystem. Total vegetation C (Tg) in the vegetated area (760385 ha) was 14.03 in forest, 3.03 in savanna and 0.66 in cropland. C stored in soil to a depth of 30 cm was 6.57 in forest, 5.30 in savanna and 11.71 Tg in cropland. CCTs of LANDSAT 4 MSS of 1982 and 1989 were used to estimate landuse changes for 650339 ha area. The forest conversion during the past 7 years resulted into a net release of 6.62 Tg vegetation C and 1.11 Tg soil C. The resultant structurally simpler vegetation had a markedly greater proportion of C in rapidly turning over components, with increased flux relative to C storage, and the latter were more tightly coupled to the rainfall variability.

INFLUENCE OF HIGH TEMPERATURE ON GRAIN GROWTH AND DEVELOPMENT IN WHEAT

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A comparative study of twenty wheat genotypes, in general, revealed depression in 1000-grain wheight due to temperature 7-8^{0}C above ambient. The extent of this depression depended upon the genotype and the week of exposure to high temperature after anthesis. Maximum decrease in grain weight was noted during second and third week in almost all the genotypes. Proximal grains suffered significant loss of grain weight due to temperature as compared to distal ones in all the spikelets of less tolerant genotype. Nutritional and moisture limitations further aggrevated the loss due to temperature. Further analysis of two contrasting genotypes revealed poor starch accumulation, low starch synthetase activity along with reduction in -SH reducing system, grain chlorophyll and grain moisture in less tolerant than relatively tolerant under temperature.

HEAT INDUCED ALTERATIONS IN ELECTRON TRANSPORT AND EMISSION PROPERTIES OF THE CYANOBACTERIUM *Spirulina platensis*

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Plant and cyanobacterial photosystems are highly sensitive to environmental stresses. The effect of heat-stress on some photosynthetic properties have been studied in *Spirulina platensis*. The heat treatment of intact cells (30-70°C) did not cause any variations in the absorption and emission properties of Chl *a*. However, the heat treatment induced changes in the quenching of F_{755} emission band at 77K associated with P700 both in intact cells and isolated thylakoids. Heat stressed cells showed a decline in pBQ. Hill activity with increase in temperatures. On the contrary, intact heat stressed cells exhibited an increase in PS I activity but not isolated thylakoids. It was also observed that heat treatment did not significantly alter NH_4Cl induced uncoupling in intact cells. Thus, we conclude that the enhancement in PS I activity in heat treated *Spirulina* cells is mostly due to increased permeability for electron donors and acceptors. (Supported by FG-IN-679).

INVOLVEMENT OF SINGLET OXYGEN IN 5-AMINO LEVULINIC ACID INDUCED PHOTODYNAMIC DAMAGE OF CUCUMBER COTYLEDONS

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5-amino levulinic acid (ALA) treated cucumber plants incubated overnight in dark accumulated excess tetrapyrroles. Upon exposure to light, the plants were damaged and died within few hours. The functions of thylakoid membrane were damaged due to the photodynamic reactions. The PS II was more susceptible to photodynamic damage than PS I. The chloroplasts isolated from ALA treated plants when exposed to light (90 W/m^2) showed about 50% inhibition of PS II reactions within 15 min of exposure. N,N-dimethyl p-nitrosoaniline (RNO) is a specific detector of singlet oxygen. RNO was found to be bleached in treated chloroplasts exposed to light (90 W/m^2) for 15 min. NaN_3, a singlet O_2 scavenger abolished bleaching of RNO in treated chloroplasts exposed to light. These suggest that singlet O_2 is the active oxygen species involved in the ALA induced photodynamic damage.

EVIDENCE FOR THE ROLE OF CYSTEINE RESIDUES OF 33 kDa PROTEIN IN Mn (II) OXIDATION

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Oxygen evolving thylakoid membranes or Photosystem II (PS II) particles exhibited a thiol dependent oxygen uptake. The protein component responsible for this oxygen uptake was identified as the extrinsic 33 kDa protein of PS II (Murata protein). Isolated protein catalysed the oxidation of Mn (II) which required the presence of Cl^- and thiol reagent such as ß-mercaptoethanol for the redox reaction. Murata protein is known to have a disulfide bridge (cys 28-cys 51) and the reduced form is active as the oxidase. The geometry of the sulfhydryl site has been probed by fluorometry using O-Phthalaldehyde (OPA). Addition of OPA to the protein inhibited its catalytic activity. A characteristic 337 nm absorption band observed in OPA bound protein indicated the formation of isoindole derivative at the Mn (II) binding site. The fluorescence emission and excitation spectra suggest conformational changes in the oxidized and reduced form of this protein. The results of these studies are suggestive that tryptophan-241 and two lysine residues are in the proximity of functional cysteine residues of the active site.

DEPENDENCE OF THE FLUORESCENCE YIELD OF CYANOBACTERIAL PHOTOSYSTEM 1 AT 77K ON P700 REDOX STATE.

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Fluorescence band at 758 nm (F758) at 77K is found in the membranes and CP1 of Spirulina frozen in the dark. Excitation spectra show that chlorophyll absorbing at 735 nm (Chl-735) is responsible for F758. This band gets bleached under the illumination of dark frozen membranes, the kinetics of F758 photobleaching is identical to that of P700 photooxidation. About 30% of the F758 initial level is reversed after 30 min dark adaptation at 77K as for $P700^+$. F758 disappears completely in the presence of ferricyanide but does not depend on ascorbate or dithionite. F758 is stable in membranes frozen with dithionite in strong light. Redox titration shows that F758 intensity has the same mid point potential as P700. Thus F758 quantum yield is proportional to P700, light induced F758 quenching is due to the energy migration from Chl-735 to $P700^+$.

ALTERATIONS IN ELECTRON TRANSPORT AND ENERGY TRANSFER IN THE SPHEROPLASTS OF THE CYANOBACTERIUM, Anacystis nidulans.

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Heavy metals are known to interfere with the primary photosynthetic processes in a variety of ways. Mercury, a common environmental pollutant has been shown to interrupt the flow of electrons at multiple sites, such as plastocyanin, the reaction centre of photosystem (PS)I, iron sulfur centres and at ferredoxin-NADP-oxidoreductase. In cyanobacteria, no such detailed investigations of the effect of mercury on photosynthetic electron transport and energy transfer processes have been made. Hence, we have studied the effect of mercury on the spheroplasts of Anacystis nidulans. Incubation of spheroplasts with mercury (6-24 μM) caused gradual decrease in the absorption by phycocyanin (PC) and PC fluorescence emission intensity and induced a slight blue shift (2 nm) in the emission peak, indicating the alterations in the emission features within the phycobilisome. $HgCl_2$ (6 μM) also suppressed the whole chain electron transport activity at much lower concentrations than require to inhibit pBQ Hill activity. Further increase in the Hg^{2+} (36 μM) caused approximately 50% inhibition in the $DCPIPH_2$ supported PSI activity which may be due to the presence of another inhibitory site near PSI. Thus mercury inhibits the electron transport at multiple sites.
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CHANGES IN THE ANTIOXIDANT SYSTEM DURING IN SITU CHLOROPLAST DEVELOPMENT IN WHEAT LEAVES

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Changes in the Antioxidant system during normal cellular and plastid development in the first leaf of 6-day-old [14 cm long] Wheat [*Triticum aestivum* L. cv. Sonalika] were investigated by examining leaf segments [S, 2 cm long] of several developmental ages present in the same leaf. Chlorophyll, Soluble protein and Water soluble sulfhydryl compounds content increased upto the 6th S starting from the base. The level of Carotenoids increased upto the 5th S and then declined but ascorbate level increased upto the 7th S. Catalase activity increased upto the 6th S while Peroxidase and Superoxide Dismutase activity increased upto the 3rd S and then declined. Glutathione Reductase activity increased till the 4th S and then declined. Ascorbate peroxidase activity decreased after the 2nd S. Thus it may be concluded that the indigenous protective mechanism against the activated oxygen species is not perfect beyond the 2nd S. Increase in the level of malondialdehyde except an initial decrease in the 2nd S, and the gradual increase in the level of total peroxide upto the 7th S, further supported our conclusion.